Larval Crab (Decapoda : Brachyura) Zoeas and Megalopas of the Scotian Shelf

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LARVAL CRAB (DECAPODA:BRACHYURA) ZOEAS AND MEGALOPAS OF THE SCOTIAN SHELF

by

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ABSTRACT

Roff, J. C., L. P. Fanning, and A. B. Stasko. 1984. Larval crab (Decapoda:Brachyura) zoeas and megalopas of the Scotian Shelf. Can. Tech. Rep. Fish. Aquat. Sci. 1264: iv + 22 p.

The distribution of larval crabs (Decapoda:Brachyura) collected in 1977 and 1978 during Scotian Shelf Ichthyoplankton and Larval Lobster Survey cruises is described. Thirty-five species of Brachyura larvae were identified from 3055 samples, including the indigenous species Chionoecetes opilio, Cancer borealis, C. irroratus, Hyas araneus, H. coarctatus, Geryon quinquedens and Carcinus maenas, and expatriate species found only as megalopa. The neuston net was the most effective gear for collecting larvae. The greatest catches occurred at night. Subsurface gears caught few larvae. Lengths and biomass estimates for the larvae of the major Canadian species are presented.

Key words: Brachyura, crab larvae, zoea, megalopa, abundance

RÉSUMÉ

Roff, J. C., L. P. Fanning, and A. B. Stasko. 1984. Larval crab (Decapoda:Brachyura) zoeas and magalopas of the Scotian Shelf. Can. Tech. Rep. Fish. Aquat. Sci. 1264: iv + 22 p.

On décrit la distribution des larves de crabes (Décapodes, Brachioures) recueillies en 1977 et 1978 lors de croisières d'étude de l'ichtyoplancton et de relevés des larves de homard effectués sur le plateau continental Scotian. L'étude de 3055 échantillons a permis d'identifier 35 espèces de brachioures à l'état larvaire, notamment les espèces indigènes Chionoecetes opilio, Cancer borealis, C. irroratus, Hyas araneus, H. coarctatus, Geryon quinquedens et Carcinus maenas, les larves des espèces exotiques étant toutes du stade mégalope. Le filet à neuston s'est révélé être l'engin le plus efficace pour l'échantillonnage des larves. Les prises les plus importantes ont été faites la nuit. On n'a capturé que quelques larves avec les engins sous-marins. On donne une estimation de la biomasse et de la longueur des larves des principales espèces canadiennes.

INTRODUCTION

There have been no previous systematic, quantitative or zoogeographic studies of the planktonic forms of the Brachyura in Canadian Atlantic waters. Previous reports from the region are limited to older literature containing a few uncertain descriptions of occurrences (see Shih, Figuera and Grainger 1971).

In the summers of 1977 and 1978, a time series of inshore and offshore lobster larval survey cruises (LLS) was done off southwest Nova Scotia to Browns Bank by the Department of Fisheries and Oceans (DFO, Fisheries Research Branch, Invertebrates and Marine Plants Division; see Stasko and Gordon 1983). During the same summers, as part of the Scotian Shelf Ichthyoplankton Program (SSIP), DFO (Fisheries Research Branch, Marine Fish Division) did several synoptic surveys from Georges Bank to Cabot Strait. Crab larvae from these cruises were separated out, a key for crab larvae of the area was developed (Roff et al. 1984), and subsamples were sorted to species and larval development stages. The present paper reports on comparisons of catches of the different gear types, on larval crab abundances and distributions, and on lengths and biomass of developmental stages.

Only a partial report on the relationships of species to water masses and environmental conditions has been attempted because of the size and heterogeneity of the data set. Also, because of the nature of the data, it was not feasible to provide any reliable estimates of growth rates, mortality rates, production or recruitment of larvae based on field data.

MATERIALS AND METHODS

GEAR TYPES, DATES AND STATIONS

A total of 3055 samples was examined for the presence of crab zoeas and megalopas (Table 1). These samples were collected during the summers of 1977 and 1978 as part of the SSIP surveys, covering the Scotian Shelf from Cabot Strait to Georges Bank, and lobster larvae surveys covering the inshore area off southwest Nova Scotia and out to the edge of the continental shelf beyond Browns Bank. Survey designation, vessels, dates and number of samples taken are summarized in Table 1.

Date, latitude and longitude, minimum and maximum depth, surface and bottom temperature, surface and bottom salinity, gear depth, type and mesh, time of day, duration of tow, speed of tow, distance to nearest shore, numbers of larvae and stages and species of crab larvae caught are available for each station (Fanning and Roff, unpublished data). Seven different gear types were used. Their characteristics and method of use are summarized in Table 2.

A comparison of catch effectiveness of each gear was made. This was done in several stages since not all gear types were fished simultaneously at any one station. The comparisons carried out and the number of observations made are presented in Table 3.

ENUMERATION AND IDENTIFICATION

Enumeration

Samples were treated in various ways. Large coelenterates, seaweed, etc were first removed. Samples containing less than 30 crab larvae were completely enumerated and identified. Samples with more than 30 crab larvae were treated as follows:

1. The total number of larvae was counted and the entire sample was scanned for rare or unusual specimens.
2. An aliquot containing a minimum of 25 and a maximum of 60 crab larvae was identified.
3. Subsampling was conducted by the beaker split method (Van Guelpen et al. 1982).
4. Numbers of each stage of each species in the total sample were calculated as follows:

e.g. Whole sample contains 250 specimens;
Whole sample is 500 mL;
Subsample volume is 100 mL and thus dilution factor is 5;
Expected number in subsample is 250/5, i.e. 50

	Z1	Z2, etc.	Total
Species 1	20	10	30
Species 2	30	0	30
Total observed			60

$$\% \text{ error} = \frac{(\text{observed} - \text{expected})}{\text{observed}} \times 100 = 20\%$$

Estimated number of larvae of Z2 species 1 in whole sample is:

$$\frac{\text{observed} \times \text{total expected} \times \text{dilution}}{\text{total observed}} =$$

$$\frac{10 \times 50 \times 5}{60} = 41.7 = 42.$$

Identification

Most specimens were identified to species and developmental stage, using published descriptions (see Roff et al. 1984). Several specimens were identified to genus or family only and assigned a name, e.g. Portunid #1A, etc.

COMPARISON OF CATCH BETWEEN GEAR TYPES

A comparison of catch per unit volume of water filtered was carried out among the seven fishing gear types. The larvae of the major species were grouped into classes by size and presumed swimming ability as shown below:

Group number	Species in the group	Development stages	Size range (mm)	Size rank
1	Cancer borealis + Cancer irroratus	zoeas I+II	0.62-0.9	2
2	Cancer borealis + Cancer irroratus	zoeas III,IV,V	1.08-1.77	4
3	Cancer borealis + Cancer irroratus	megalopas	2.41-2.46	6
4	Hyas coarctatus + Hyas araneus	zoeas I+II	1.07-1.45	4
5	Hyas coarctatus + Hyas araneus	megalopas	2.2 -3.2	6
6	Chionoecetes opilio	zoeas I+II	1.32-2.12	5
7	Chionoecetes opilio	megalopas	3.58	7
8	Carcinus maenas	zoeas I+II	0.52-0.69	1
9	Carcinus maenas	zoeas III+IV	0.91-1.09	3
10	Carcinus maenas	megalopas	1.23	4

Comparisons were made only where at least one of the gear types caught larvae in at least one group. The following sets of comparisons were possible (Table 3):

Comparison A	Gears 1, 4, 5
Comparison B	Gears 1, 2, 3
Comparison C	Gears 1, 2, 6, 7

Within comparison A, 186 stations were compared; within comparison B, 122 stations were used; and within comparison C, 22 or 23 stations were used.

Univariate descriptive statistics (number of observations, mean, standard deviation, standard error, variance, probabilities associated with the t- and F-statistics) were calculated between gear types for all data sets, using $\log_{10}$ transformed counts of larvae. This approach was used to decide whether sufficient data were available for a between-gear comparison, and to rank the efficiency of gear types (catch per unit volume).

Gear types were ranked as follows:

- subequal when mean catch differed by less than 2x.
- greater when mean catch differed by 2.1 to 9.9x.
- much greater when mean catch differed by 10x or greater.

An analysis of variance followed by Duncan's New Multiple Range test was used to locate significant differences between gear catches.

DISTRIBUTIONS, ABUNDANCE AND MAPPING

Neuston net samples were used to calculate abundances and give distribution patterns. Abundance was calculated as number (sum of zoeas or megalopas) per 550 m^3 of water filtered (volume per neuston net tow), assuming 100% filtration efficiency. No attempt has been made to present seasonal changes in distribution patterns. Distributions presented here are seasonal averages only, combined for the 2 yr of study.

The sampling area extended from Cabot Strait to Georges Bank and from Grand Manan Island in the Bay of Fundy to beyond Sable Island at the edge of the shelf. The area sampled and grid pattern used (intervals of 30' latitude and 60' longitude) are shown in Fig. 1. The number of stations sampled within each of these grids is also shown in Fig. 1. Within each grid the mean abundances of each species (as sum of zoeas and megalopas separately) were calculated and plotted.

DIEL VARIATIONS IN AVERAGE CATCH

Cancer borealis, Cancer irroratus, and Chionoecetes opilio were selected for comparisons of average catches per 1000 m^3 of water filtered at different times of day. Abundance was summed for all stages within a species and divided by the number of samples to obtain a figure for average catch per 1000 m^3.

The day was divided into three periods: daylight hours (0700-2000), night (2200-0500), and a combined dawn-dusk period (0500-0700 + 2000-2200). Data were used from all gear types which were fished concurrently at the stations considered. Separate calculations were made for the SSIP cruises alone and for the SSIP and LLS cruises combined.

LENGTHS AND BIOMASS OF DEVELOPMENTAL STAGES

The following species (of commercial or potential commercial importance) were subjected to length and weight determinations, by developmental stage, as an initial step to growth and production studies:

Cancer borealis
Cancer irroratus
Carcinus maenas
Chionoecetes opilio
Hyas araneus
Hyas coarctatus
Geryon quinquedens

Length measurements in all stages were taken as the carapace length parallel to the longitudinal axis. For zoeal stages this was taken from the rear of the eyesocket to the furthest posterior edge of the carapace. For the megalopa it was taken from the tip of the rostrum to the furthest posterior edge of the carapace.

For weight determinations, animals were picked by hand, rinsed briefly in distilled water, and placed on aluminum or platinum pans as necessary for subsequent treatment. At least three replicate determinations were made for each developmental stage of each species, using up to 12 animals per pan in the case of smaller zoeal stages. Pans were dried at 55°C in an oven for 12 h followed by cooling in a desiccator before re-weighing. Samples were then ashed at 550°C for 30-60 min, depending on sample size, allowed to cool again in a desiccator and then re-weighed. Weights were then calculated as loss-on-ignition (i.e. ash-free-dry weight (AFDW)), and the percentage ash was calculated for each developmental stage of each species.

POPULATION DYNAMICS (GROWTH)

No time-dependent analysis of the SSIP cruise data was attempted because the seasonal coverage was inadequate. For the LLS data, groups of stations off southwest Nova Scotia were selected as representative of a restricted geographical area. Each growth stage (zoea 1, 2, etc. and megalopa) was summed between stations and plotted against time. The construction of such (potential) instar growth curves was attempted for the three most abundant species in this region, Cancer borealis, Hyas araneus and H. coarctatus. It was hoped that rates of molting and mortality between the zoeal and megalopa stages could be deduced as the season progressed, and that some estimates of production of the instars might be obtained from collections of the LLS cruises.

RESULTS AND DISCUSSION

The present study represents the first extensive investigation and analysis of Scotian Shelf brachyuran larvae; 3055 samples were examined. A substantial effort was put into taxonomic examination of the samples and microscopic examination of specimens to verify species characters. It is now possible to identify and distinguish the developmental stages of virtually all the indigenous larval Brachyura of the Canadian Atlantic region, including the commercially significant species.

SPECIES AND ABUNDANCE OBTAINED

Thirty-five taxa of larval Brachyura were distinguished and 629,270 zoeas and megalopas have been counted. A complete list of these taxa and their abundances is given in Table 4.

In all, 21 taxa have been identified to the species level, 2 taxa to the generic level, 3 taxa to subfamily and 3 to family. Despite recourse to outside expertise (Roff et al. 1984), 6 taxa remain undefined even at the family level.

The greatest taxonomic problem concerned the family Portunidae, the swimming crabs. This family contains many species whose larvae are not yet described. Most of the portunids encountered were not indigenous to Canadian Atlantic waters as adults, but are larval expatriates from south of Georges Bank.

Serious taxonomic problems were also encountered with the two Cancer species in distinguishing them at each developmental stage. This finally involved a complete appendage analysis. The final diagnostic characters (see Roff et al. 1984) are believed to be reliable.

Of the brachyuran species known to inhabit Canadian Atlantic waters as adults, only one remains totally unknown in larval stages, viz: Euprognatha rastellifera, although there are no published descriptions yet for three others, viz: Portunus sayi, Arenaeus cribrarius, and Acanthocarpus alexandri.

SPATIAL DISTRIBUTION AND ABUNDANCES OF SPECIES

The sampling intensity in the SSIP cruises along the Scotian Shelf and the LLS cruises off SW Nova Scotia was different in space and time; the area offshore from SW Nova Scotia has been much more intensively sampled (see Fig. 1).

Accordingly, frequencies of occurrence of species should be critically interpreted as geographical ranges or abundances. Occurrence of a species in an area is significant, but its absence elsewhere may not be. Efforts to determine a species origin or settling location from known water movements are often inaccurate.

Distributions have been considered for convenience under a number of headings.

Temperature and salinity

The average summer temperature (°C) and salinity (o/oo) are shown in Fig. 2 and 3, respectively. Temperature ranged from 0°C to over 20°C. There is a general pattern of temperature increase from north to south and from inshore to offshore. Relationships between temperature and species ranges will be given in the appropriate subsections; maximum and minimum temperatures at which each species was observed are presented in Table 5.

Salinities ranged between 27 o/oo inshore to just over 35 o/oo offshore. Again, there are distinct north-south and inshore-offshore increases in salinity. The maximum observed salinity (35.1 o/oo) corresponds to the edge of Gulf Stream waters. The outer boundary of the sampling area will be influenced by slope water of salinities between 33.5 and 35 o/oo. The majority of the area sampled is clearly influenced by coastal waters of salinities between 30 and 33.5 o/oo. The maximum and minimum salinities at which each species was observed are presented in Table 5.

The major species in Canadian waters

Chionoecetes opilio larvae were taken up to 230 km from shore at temperatures between 5.6 and 18.5°C, and within a range of salinities between 30 and 32.36 o/oo (Table 5). C. opilio occurred abundantly as zoeas (stages I and II) to the south and east of Cape Breton, reaching concentrations of about 400 animals per 1000 m^3, with a few zoeas found all along the Scotian Shelf and even beyond Yarmouth into the Bay of Fundy (Fig. 4). Surprisingly, most C. opilio megalopas were taken off southern Nova Scotia and even beyond Yarmouth into the Bay of Fundy (Fig. 5). The average number per neuston haul was always less than one however. Possibly sampling in the northern part of the Scotian shelf occurred either too early or too late to catch the megalopa stages there. The question of location of the spawning adult stock will be left open at present because larval development in Brachyura can be quite slow and considerable drift of larvae from point of origin could have occurred. An adult spawning stock of C. opilio occurs off Cape Breton, and the larvae which take up to 2 mo to develop in the plankton (Davidson et al. 1982) could have drifted southwest. However, recent reports (Dadswell, pers. comm.) note the presence of small populations of C. opilio within the Bay of Fundy, and megalopas off the SW Nova Scotia area could be derived from this population.

Hyas araneus larvae were taken up to 310 km from shore at temperatures between 4.2 and 19.5°C, and over a salinity range of about 30-33 o/oo (Table 5). H. araneus also occurred mostly as zoeas (stages I and II) to the south and east of Cape Breton with numbers approaching an average of 1000 zoeas per 1000 m^3. Zoeas were found all along the Scotian Shelf and, overall, the distribution pattern is similar to that of C. opilio zoeas, with some animals being found in the outer part of the Bay of Fundy (Fig. 6). All the megalopas of H. araneus (Fig. 7) were taken off southwest Nova Scotia, often in substantial numbers, and mainly close to shore. Again, sampling in the northern part of the Scotian Shelf may have missed the seasonal occurrence of the megalopa stage there.

Larvae of Hyas coarctatus were taken up to 290 km from shore at surface temperatures between 0 and 20.3°C, and at salinities between 29-33 o/oo (Table 5). H. coarctatus had two centers of abundance for the zoeal stages, one to the east of Cape Breton and the second around southern Nova Scotia (Fig. 8), with few animals in between. Again, the megalopa of this species was collected in the coastal area (Fig. 9) off southern Nova Scotia, with none observed further north than Halifax.

Larvae of Cancer borealis were taken at surface temperatures between 0 and 20.3°C and from surface salinities between about 30-33 o/oo (Table 5). They were encountered both very close to shore and as far offshore as 300 km. C. borealis zoeas (stages I-V) were common in coastal waters throughout the Scotian Shelf area (Fig. 10), with a tendency for numbers to decrease with distance from shore. The megalopas of this species were less commonly encountered except for one region just off the Shelf (Fig. 11), which may represent an influx of megalopas derived from adults south of Georges Bank.

Larvae of Cancer irroratus were observed at surface temperatures from 2-22.1°C and at surface salinities from less than 28 to over 35 o/oo (Table 5). C. irroratus zoeas (stages I-V) and megalopas were abundant to very abundant throughout the sampling area (Fig. 12, 13). Numbers exceeded 1000 per neuston haul (550 m^3) both inshore and offshore, perhaps indicating a double origin for these larvae, both indigenous larvae (inshore) and southern expatriates (offshore). Average numbers of larvae for C. irroratus were much higher than for C. borealis; it is not clear whether this may be partly or largely due to differences in seasonal timing of development and the timing of the SSIP cruises.

Larvae of Carcinus maenas were found at temperatures from 5-18°C and at salinities from about 31.5-32.5 o/oo (Table 5). Zoeas (stages I-IV) and megalopas were common, but restricted to the shore off SW Nova Scotia (Fig. 14 and 15, respectively). They are clearly derived from a local indigenous population of adults.

Larvae of Geryon quinquedens were collected at temperatures ranging from 6-19.5°C and at salinities from about 29 to about 33 o/oo (Table 5). The zoeas were collected in coastal waters, and were also collected up to 270 km offshore, and appear to be derived from an indigenous adult stock. Substantial numbers of G. quinquedens zoeas were taken during this study (Table 4). They were found mainly between Georges Bank and SW Nova Scotia, with some offshore from Halifax (Fig. 16). Megalopas of the species have been previously recorded in the Georges Bank area (material from M. J. Dadswell).

Other species found only as megalopa stage

Three further species known to inhabit Canadian waters as adults were taken as megalopas. Acanthocarpus alexandri (Fig. 17) was rare and limited to the very edge of the Shelf from Georges Bank (61°W Long.). The range of adults of this species extends to about 370 m.

Neopanope texana sayi and Ovalipes ocellatus both inhabit shallow water (down to about 35 m) as adults. Their distributions here (Fig. 18 and 19, respectively) as megalopas were predominantly offshore, indicating a probable origin from a southern adult stock.

Southern expatriates

Several species unknown as adults in Canadian coastal waters were found offshore as megalopas. All of them show similar distribution patterns, predominantly occurring along the edge of the continental shelf. This 'edge effect' may be an artefact because sampling did not extend far beyond the edge of the shelf and they may be more abundant further offshore.

Cycloës bairdii showed clear centers of abundance between 62 and 66°W Long. along the edge of the shelf, with numbers diminishing inshore (Fig. 20). Although absolute abundances were considerably lower, Parthenope pourtalesii, Calappa flammea and Lyreidus bairdii showed similar distribution patterns (Fig. 21, 22 and 23, respectively). The distribution pattern of Dromidia antillensis (an Anomuran) has also been included here as an example of a southern species whose larvae were found very close to shore (70 km) off SW Nova Scotia (Fig. 24).

The portunids

Six species of the family Portunidae (only one of which could be identified satisfactorily as a Portunus species) were found only as megalopas. This suggests that they must be southern expatriates. These six species are numbers 13, 14, 15, 16, 17 and 18 (unknown portunids 1A, 1B, 2, 3, 4 and 5, respectively) (Table 4).

Arenaeus cribrarius of the subfamily Portuninae is found in Canadian waters, but is undescribed beyond zoea I. It is known to inhabit shallow water close to shore as adults. Its larval distribution would therefore be expected to be like that of Carcinus maenas (Fig. 14, 15). It is unlikely that any of these species can be A. cribrarius because none of the portunid megalopa distributions conform to such a pattern (Fig. 25-30). Portunus sayi, also known from Canadian waters, is normally pelagic as an adult; it is possible that one of these portunids could be the megalopa of this species.

Other species

Three unidentified species (numbers 22, 36 and 37; unknowns 9, 18 and 19, respectively) were observed infrequently. Until such time as these species can be identified, we cannot learn much from their distributions (Table 5).

Five species (numbers 11, 24, 26, 28 and 32) were not taken in neuston samples. Their observed limits of distribution are given in Table 5. Of these species, only Callinectes sapidus could represent indigenous Canadian fauna; however, its distance from shore suggests that it is a southern expatriate.

The three taxa, 29, 30 and 31 (Cancer sp., Hyas sp. and unidentifiable, respectively) were necessary for enumeration purposes. Each includes at least two possible species. Their distributions will not be considered further here.

Six species were each observed at only one location (species numbers 8, 27, 33, 34, 35 and 38) (Table 5). Only one of these, Bathynectes superbus, is possibly indigenous. Species 27, probably a Pinnotheres sp., does not resemble either of the indigenous Canadian species. Its location, with the southern expatriate Parthenope serrata, at the edge of the continental shelf just north of Georges Bank, suggests that it too is a southern form.

Species diversity

Maximum numbers of species per haul were calculated for each grid sampled (Fig. 31). Certain features of species distributions are apparent which can be summarized as follows:

- Inshore diversity was variable, the maximum number of species observed was 7, off SW Nova Scotia;
- Diversity is reduced in the Bay of Fundy where a maximum of 2 species are observed;
- Diversity is consistently highest at stations along the edge of the continental shelf, where up to 17 species were encountered in a single haul.

GEAR COMPARISON AND DEPTH DISTRIBUTION OF CRAB LARVAE

In many cases the various gear types clearly fished and retained larvae differently. Results consistently indicate that larval crabs are strongly associated with the neustonic layer. In the majority of cases the neuston net was clearly superior in terms of catch per 1000 m^3 of water filtered. This gear was followed by the 1-meter, the 0.15-meter and the 0-meter nets, with the two Isaacs-Kidd midwater trawls (IKMT) being much less efficient and the Bongo being decidedly the least efficient of the gears. A summary of results by species group and gear type is presented in Table 6. The ranking of gears by catch per unit volume is presented in Tables 7 and 8.

In all cases the Bongo net and the 0.9-m and 1.8-m IKMT caught few larval crabs; their catches were often two orders of magnitude less than in the neuston or meter nets. One reason for their low catch is that these gears are hauled obliquely from depths close to the bottom. They are thus filtering a considerable volume of water which either does not contain, or which contains only sparse populations of larval Brachyura.

The neuston net was consistently superior in performance to the meter nets in the LLS surveys, where all nets had the same mesh size (1179 um) and towing speed (2 $m \cdot sec^{-1}$). It was sometimes inferior in performance where total catches were low, probably due to patchiness. The neuston net outfished the 0-meter net (towed at the surface) on all occasions. The 1-meter net (towed with top of ring at 1-m depth) was more efficient than the neuston net on two occasions. A circular net fished entirely beneath the surface may, under some conditions, encounter a stratum of higher larval abundance. For example, in rough weather, even strongly swimming, positively phototactic animals are driven deeper in the water column, probably below the range of the neuston net. A combination of neuston and 1-meter nets may be appropriate for quantitative collection of larval Brachyura.

Many Brachyura larvae can potentially escape through 1179-µm meshes (diagonal aperture ≃1.7 mm). The relevant dimension determining retention or escapement is probably carapace length (excluding spines since they are deformable). Based on this length (Table 9), the following stages of the abundant local species would experience significant escapement through an 1179-µm mesh: C. opilio zoea I only, H. araneus and H. coarctatus zoeas I and II, C. quinquedens zoeas I-IV, C. irroratus and C. borealis zoeas I-V, C. maenas zoeas I-IV, and megalopas.

Most zoeas and several megalopas collected during this study can therefore be regarded as probably undersampled. To retain all zoeas, even of the commoner species, a mesh size of less than 500 µm is required and preferably a mesh of 250 µm.

A smaller mesh size (471 µm) and slower towing speed (1.2 $m \cdot sec^{-1}$) were used in the 0.15-meter net (towed at 15-cm depth) collections. The combination of finer mesh with slower towing speed should increase capture efficiency for smaller larvae, but might increase avoidance by larger ones. In fact, these expectations are, if anything, reversed (see

comparison C, Table 7; size ranges and ranks of groups). The neuston net performed better than the 0.15-meter net in catching the very small C. borealis and C. irroratus zoeas I and II, and also outfished the 0.15-meter net for groups 2 and 3 (size ranks 4 and 6). However, the 0.15-meter net outfished the neuston net for groups 4 and 5 (in the same size ranks 4 and 6).

These catch differences between the 0.15-meter and neuston nets cannot be explained on the basis of reduced mesh size and towing speed. The data indicate that different stages and species inhabit different strata close to the surface. For example, Hyas sp. zoeas and megalopas and C. maenas zoeas I-IV showed a weak tendency to be more numerous at 1 m than at the surface (Table 7). Thus, slight differences in vertical distributions of various species and stages appear to confound the effects of gear selectivity.

DIEL VARIATION IN AVERAGE CATCH

There were considerable differences in average catch over a 24-h period. When LLS and SSIP cruises were considered together, a bias is introduced because the LLS surveys were conducted mainly in daylight hours (Table 10). Despite this, there is still a marked difference in day-night abundances. Cancer borealis is 3x more abundant at night, C. irroratus is about 6x more abundant at night, and Chionoecetes opilio larvae are nearly 30x more abundant at night on average. Catches in the dawn-dusk period tended to be intermediate between day and night catches.

When the SSIP cruises are considered alone, an even sharper difference between day and night abundances was evident (Table 10). For all three species, average abundances at night were 50-100x greater than during the day, and in each species the dawn-dusk period shows intermediate values.

A number of important points should be stressed:

(i) The increased abundances of these species in the neuston and meter nets at night are clear evidence of diel vertical migration.

(ii) Future attempts to estimate abundances of Brachyura larvae must consider this strong pattern of diel variation. Clearly there will be biases introduced into the distribution maps (Fig. 4-30) presented above. These maps are based only on order-of-magnitude numbers and contain both day and night samples; therefore, the biases are probably tolerable for the purposes of describing geographic ranges. The general result will have been to underestimate abundances in the LLS surveys around SW Nova Scotia in inshore areas.

(iii) These results should not affect the depth distribution and gear comparison results appreciably because all gears were fished simultaneously at the same time of day, and again comparisons were made on an approximate 'order-of-magnitude' basis.

LENGTHS AND BIOMASS

Average lengths and mean dry weights for the developmental stages of the seven major species are shown in Table 9. Two points should be noted regarding weights. Firstly, the ash content of the larval Brachyura is quite low; it varied from 2.3 to 5.3% and averaged 4.0% of the dry weight. Ash content in the megalopas of all species was very similar. Secondly, these weight estimates have been made on specimens preserved in formalin and then alcohol. Therefore, the figures presented here are liable to be low compared to estimates on fresh material (Omori 1978).

During the course of this study, it became apparent that there was a clear bimodality in the length and weight frequency distributions in C. opilio. The smaller forms were very apparent in the second zoeal stage and have been designated here as 'mini Z2' (see Table 9). Further work on the origins of this bimodality in the larvae and its relationship to morphometric and meristic variation in the adult population is now being undertaken.

A brief comparison of differences in sizes between laboratory-reared and field-collected specimens has been undertaken. A fairly consistent pattern has emerged showing that field specimens are generally larger than laboratory specimens. This may simply be a function of temperature at which larvae were raised but, in view of other anatomical differences between laboratory and field animals (Roff et al. 1984), this point is worth noting. A qualitative comparison of sizes is presented in Table 11.

GROWTH RATES

Estimates of growth rates in three species have been made from LLS data in the SW Nova Scotia area, at ambient temperatures of 11.0 to 13.0°C. An example of the seasonal pattern from which these growth estimates have been made is shown in Fig. 32.

In C. borealis, one estimate of the interval from Z1 to Z5 was about 30 d (Fig. 32), and a second estimate gave a time from Z2 to Z5 of 28 d. Thus an extrapolated estimate of time from hatching to megalopa might be about 5 to 6 wk at 10.0 to 15.0°C. In H. coarctatus, one estimate of development time from Z1 to megalopa gave 34 d, and Z1 to Z2 of 13 d. In H. araneus, the interval from Z1 to megalopa appeared to be about 42 d. These figures are in reasonable agreement with laboratory development times at similar temperatures (Sastry, pers. comm.; Christiansen 1973).

SUMMARY

1. A total of 629,270 larval Brachyura have been identified to species and development stage in 3,055 samples covering the entire Scotian Shelf. Thirty-five taxa have been recognized, of which 21 are identified to species and a further eight to genus or family.

2. Only one indigenous brachyuran, Euprognatha rastellifera, remains completely unknown in larval stages. It is now possible to distinguish most brachyuran larvae of the Canadian Atlantic region.

3. Spatial distributions and abundances were presented for each species. Because of lack of coverage in certain seasons in certain areas

(notably the northeast Scotian Shelf) these patterns should be cautiously interpreted. The unexpected dearth of Hyas and Chionoecetes in the Cabot Strait area probably results from such a seasonal sampling bias.

4. The indigenous species Chionoectes, the two Hyas sp., the two Cancer sp., Carcinus, and Geryon were predominantly found in coastal waters.

5. The southern expatriates include the portunids, Cycloës, Dromidia, Lyreidus, Calappa, Ocypode, Uca, Callinectes, Acanthocarpus, Neopanope, and four unknowns. They were mainly associated with the slope water at the edge of the continental shelf, although incursions into coastal areas by several species occurred.

6. Comparisons of catch per unit of water filtered showed that the neuston net was consistently the most efficient samrler, followed by the meter net. Bongo nets and Isaacs-Kidd midwater trawls (IKMT) are extremely inefficient for the near-surface Brachyura.

7. All gears must have undersampled the early developmental stages of most species. To efficiently retain larvae down to zoea I, a mesh size of about 250 µm is required.

8. Length and individual biomass weights have been determined for the major species. Ash content in all species averaged about 4.0%. A length bimodality in C. opilio stage II zoeas has been observed but its cause is at present unknown. A comparison of sizes between field-collected and laboratory-reared specimens showed that field specimens are generally larger and more highly setose (especially on swimming appendages) than laboratory specimens.

9. It has not proved possible to estimate field growth, mortality or recruitment rates.

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Table 1. Cruises, dates, and numbers of collections analyzed (by gear type).

#	Survey	Vessel	Dates		Gear							
			from	to	Neuston 1[a]	.15-meter 2	IKMT-0.9m 3	0-meter 4	1-meter 5	IKMT-1.8m 6	Bongo 7	Total
1	LLS 1977 inshore	Sea Ghost	28.06.77	06.07.77	33	0	5	0	0	0	0	38
2	" " "	" "	08.07.77	14.07.77	33	18	3	0	0	0	0	54
3	" " "	" "	26.07.77	30.07.77	29	25	4	0	0	0	0	58
4	" " "	" "	08.08.77	12.08.77	34	30	8	0	0	0	0	72
5	" " "	" "	16.08.77	20.08.77	30	25	5	0	0	0	0	60
6	" " "	" "	22.08.77	27.08.77	31	33	4	0	0	0	0	68
7	" " "	" "	12.09.77	18.09.77	34	27	6	0	0	0	0	67
11	LLS 1977 offshore	J.L. Hart	05.07.77	07.07.77	12	10	12	0	0	0	0	34
12	" " "	Marj + Mindy	19.07.77	23.07.77	21	22	20	0	0	0	0	63
13	" " "	" "	01.08.77	04.08.77	32	30	28	0	0	0	0	90
15	" " "	" "	08.08.77	10.08.77	30	28	25	0	0	0	0	83
16	" " "	" "	22.08.77	25.08.77	25	21	20	0	0	0	0	66
17	" " "	" "	12.09.77	16.09.77	29	31	28	0	0	0	0	88
20	Georges Bank	E.E. Prince	07.07.77	20.07.77	62	39	0	0	0	0	0	101
22	Grand Manan	J.L. Hart	14.09.77	16.09.77	11	7	0	0	0	0	0	18
30	LLS 1978 inshore	Daryl + Eric	03.07.78	07.07.78	29	0	0	30	8	0	0	67
31	" " "	" "	11.07.78	15.07.78	26	0	0	24	26	0	0	76
32	" " "	" "	24.07.78	28.07.78	30	0	0	31	29	0	0	90
33	" " "	" "	31.07.78	06.08.78	30	0	0	0	32	0	0	62
34	" " "	" "	07.08.78	11.08.78	32	0	0	0	33	0	0	65
35	" " "	" "	14.08.78	18.08.78	31	0	0	0	34	0	0	65
36	" " "	" "	21.08.78	25.08.78	30	0	0	0	37	0	0	67
37	" " "	" "	28.08.78	02.09.78	32	0	0	0	42	0	0	74
38	" " "	" "	04.09.78	10.09.78	29	0	0	0	35	0	0	64
39	" " "	" "	18.09.78	22.09.78	30	0	0	0	19	0	0	49
40	LLS 1978 offshore	J.L. Hart	07.07.78	07.07.78	3	0	0	3	3	0	0	9
41	" " "	Adventure	12.07.78	15.07.78	22	0	0	22	22	0	0	66
42	" " "	J.L. Hart	12.07.78	14.07.78	16	0	0	16	16	0	0	48
43	" " "	Adventure	24.07.78	27.07.78	30	0	0	26	24	0	0	80
44	" " "	"	01.08.78	04.08.78	24	0	0	25	24	0	0	73
45	" " "	"	14.08.78	17.08.78	25	0	0	26	24	0	0	75
46	" " "	"	21.08.78	24.08.78	24	0	0	24	24	0	0	72
51	SSIP 1978 L005	Lady Hammond	09.08.78	16.08.78	51	0	0	0	0	0	0	51
52	" " L006	" "	20.08.78	01.09.78	88	0	0	0	0	0	0	88
53	" " L007	" "	06.09.78	08.09.78	14	0	0	0	0	0	0	14
54	" " CC02	Canso Condor	17.05.78	13.07.78	393	46	0	0	0	0	0	439
55	SSIP 1977 CL01	Canso Light	08.08.77	02.09.77	167	169	0	0	0	32	33	401
			TOTAL		1602	561	168	227	432	32	33	3055

[a]gear code

Table 2. Specification of collecting gear used, with method of operation.

Gear code	Gear	Depth and method of tow	Speed of tow $m \cdot sec^{-1}$ (knots)	Mesh size μm	Duration of tow (min)
1	Neuston net	0-15 cm; horizontal	2-2.5 (4-5)	1179	30
4	Meter net	0-100 cm; horizontal	2 (4)	1179	30
2	Meter net	15-115 cm; horizontal	2 (4)[a]	1179	30
5	Meter net	100-200 cm; horizontal	2 (4)	1179	30
3	0.9-m IKMT	stepwise oblique: 10 min at 37 m (20 fm) 10 min at 7.5 m (4 fm) 10 min at 2 m (1 fm)	2 (4)	471 (codend)	30
6	1.8-m IKMT	stepwise oblique: from 5 m above bottom to surface in 6 equal steps of 5 min each	2.7 (5.5)	471 (codend)	30
7	Bongo net	standard oblique (MARMAP)	$\simeq$1.2 ($\simeq$ 2.5) to maintain 45° wire angle	471	30

[a]During the SSIP cruises on Canso Condor and Canso Light, the towing speed was 1.2 $m \cdot sec^{-1}$ (2.5 knots) and the mesh size was 471 μm.

Table 3. Gear comparisons which were made by using 10 groups of crab larvae.

Comparison	Survey	Year	Gear code	Gear name	No. of observations
A	SW Nova Scotia Lobster Larvae Survey	1978	1	neuston net	186
			4	meter net	186
			5	meter net	186
B	SW Nova Scotia Lobster Larvae Survey	1977	1	neuston net	122
			2	meter net	122
			3	IKMT (0.9 m)	120
C	Scotian Shelf Ichthyoplankton Survey	1977	1	neuston net	23
			2	meter net	22
			6	IKMT (1.8 m)	22
			7	Bongo	22

Table 4. total abundance of species obtained in all collections; ? = species designation not definite.

Species code	Unknown designation	Species name	Total abundance
1		Cancer borealis	24,044
2		Cancer irroratus	364,043
3		Hyas coarctatus	147,742
4		Hyas araneus	44,460
5		Chionoecetes opilio	3,813
6		Geryon quinquedens	1,449
7		Carcinus maenas	14,061
8		Bathynectes superbus	9
9		Ovalipes ocellatus	--
10	#4	Neopanope texana sayi	35
11	#6	Ocypode quadrata	48
12	#5	Dromidia antillensis	151
13	Portunidae #1A	Subfamily Portuninae	643
14	Portunidae #1B	Subfamily Portuninae	13,773
15	Portunidae #2 (2A)	Portunus spp.	1,113
16	Portunidae #3	Family Portunidae	134
17	Portunidae #4	Callinectes ornatus (?)	206
18	Portunidae #5	Subfamily Portuninae	326
19	#3	Cycloës bairdii (?)	9,452
20	#7	Acanthocarpus alexandri (?)	6
21	#8	Lyreidus bairdii (?)	46
22	[illegible]	Family Grapsidae or Xanthidae	14
23	#10	Calappa flammea	43
24	#11	Uca spp. (?)	3
25	#12	Parthenope pourtalesii (?)	128
26	#13	Ethusa microphthalma (Dorippidae)	2
27	#14	Family Pinnotheridae	1
28		Callinectes sapidus	--
29		Cancer spp.	658
30		Hyas spp.	617
31		Species unidentifiable	2,168
32	#15	--	--
33	#20	--	--
34	#17	--	--
35		Parthenope serrata	1
36	#18	--	25
37	#19	--	6
38	#16	--	50
		TOTAL	629,270

Table 5. Geographical, distance from shore, surface salinity and temperature extremes of larval crabs.

No.	Species	North ° /	South ° /	Distance from shore min (km)	Distance from shore max (km)	Depth max (m)	Surface salinity °/oo min	Surface salinity °/oo max	Surface temperature °C min	Surface temperature °C max
1	C. borealis	46 43	40 56	4	300	154	29.60	33.01	0.00	20.30
2	C. irroratus	47 10	40 35	4	335	225	27.72	35.05	2.00	22.10
3	H. coarctatus	47 10	41 08	4	290	83	28.86	33.01	0.00	20.30
4	H. araneus	47 01	41 22	4	310	150	29.79	33.01	4.20	19.50
5	C. opilio	47 10	42 20	9	230	51	29.87	32.36	5.60	18.50
6	G. quinquedens	44 59	41 06	13	270	40	28.86	33.01	6.00	19.50
7	C. maenas	44 25	42 32	4	18	20	31.46	32.45	5.00	18.00
8	B. superbus	43 51	43 51	90	90	0	31.10	31.10	19.70	19.70
9	O. ocellatus	--	--	---	---	--	--	--	--	--
10	N. texana sayi	43 41	42 17	105	125	79	31.02	31.47	12.90	18.00
11	O. quadrata	43 00	40 56	42	300	0	29.96	33.05	9.00	21.10
12	D. antillensis	44 15	40 43	70	300	65	30.90	33.01	9.50	20.10
13	Portunid 1A	44 27	40 56	25	300	79	30.79	35.05	10.00	20.90
14	Portunid 1B	45 03	40 35	13	335	225	28.86	35.05	8.50	21.10
15	Portunid 2	44 28	40 35	40	335	154	30.93	33.05	10.00	21.10
16	Portunid 3	43 18	40 50	40	240	84	30.86	32.73	10.00	20.50
17	Portunid 4	44 27	41 06	40	270	68	31.13	33.01	9.00	20.60
18	Portunid 5	44 38	40 35	115	335	43	31.13	32.88	16.20	20.50
19	Cycloës bairdii (?)	44 39	40 35	13	335	154	28.86	35.05	8.50	20.90
20	A. alexandri (?)	43 01	41 06	155	270	0	31.31	35.05	14.50	20.90
21	Lyreidus bairdii (?)	43 12	41 03	95	270	20	31.06	32.36	9.50	17.00
22	Unk 9	43 12	42 21	40	190	1	31.44	32.56	11.50	19.80
23	Calappa flammea	43 41	41 06	105	270	0	30.93	32.81	13.70	19.50
24	Uca spp.	42 45	42 21	70	95	79	31.44	31.44	16.00	19.00
25	Parthenope pourtalesii	44 01	41 37	40	275	79	31.02	35.05	8.80	20.90
26	Ethusa microphthalma	42 45	42 33	70	95	20	--	--	18.00	19.00
27	Pinnotheres sp.	42 21	42 21	---	---	0	31.44	31.44	17.70	17.70
28	Callinectes sapidus	43 01	40 35	210	335	0	31.78	35.05	20.10	22.10
29	Cancer sp.	45 04	42 17	4	250	83	30.29	32.88	7.80	19.20
30	Hyas sp.	47 00	42 09	4	280	37	30.21	32.27	5.30	18.30
31	Unidentifiable	46 43	42 20	4	295	20	29.64	32.82	5.20	19.20
32	Unk 15	42 32	42 22	110	125	20	--	--	15.00	16.00
33	Unk 20	44 26	44 26	325	325	0	32.45	32.45	8.70	8.70
34	Unk 17	42 21	42 21	---	---	0	31.44	31.44	17.70	17.70
35	Parthenope serrata	42 21	42 21	---	---	0	31.44	31.44	17.70	17.70
36	Unk 18	42 23	42 10	---	---	65	31.44	33.01	17.70	18.50
37	Unk 19	42 21	42 09	---	---	43	31.44	33.01	17.70	18.50
38	Unk 16	42 23	42 23	---	---	0	31.44	31.44	17.70	17.70

Table 6. Results of comparisons between gear types (analysis of variance and Duncan's tests). H_0: the mean catches by the two gear types within a given group of larvae, are equal; H_A: the means are not equal (n = number of samples).

	Comparison sets																	
	A (n = 186)			B (n = 122)			C (n = 22)											
Gear Pair	1-4	1-5	4-5	1-2	1-3	2-3	1-2	1-6	1-7	2-6	2-7	6-7						
Group																		
1	R	R	A	R	R	R	A	A	A	A	A	A						
2	R	A	A	R	R	R	A	A	A	A	A	A						
3	A	A	A	R	R	R	A	A	A	A	A	A						
4	A	A	A	A	R	R	A	A	A	A	A	A						
5	A	A	A	R	R	R	A	A	R	A	A	A						
6	-	A	A	A	A	A	-	-	A	-	A	A						
7	-	A	A	A	A	A	A	A	A	A	A	A						
8	A	A	A	-	-	-	-	-	-	-	-	-						
9	A	R	R	A	A	A	-	-	-	-	-	-						
10	-	-	-	-	-	-	-	-	-	-	-	-						

A - accept H_0, R - reject H_0 : accept H_A (at $\alpha = 0.05$).
For groups of larvae 9-10, see text.
For gear codes, see Table 2.

Table 7. Ranking of gears by catch of larvae per 1000 m^3 of water filtered.

Comparison A		Ranking in order of catch
Group	1	Neuston > 1-meter ≈ 0-meter
	2	Neuston > 1-meter ≈ 0-meter
	3	Neuston >> 1-meter > 0-meter
	4	Neuston ≈ 1-meter ≈ 0-meter
	5	insufficient data
	6	insufficient data
	7	insufficient data
	8	1-meter > 0-meter ≈ Neuston
	9	1-meter > Neuston ≈ 0-meter
	10	no data

Comparison B		Ranking
Group	1	Neuston > 0.15-meter > 0.9-m IKMT
	2	Neuston >> 0.15-meter >> 0.9-m IKMT
	3	Neuston >> 0.15-meter >> 0.9-m IKMT
	4	Neuston > 0.15-meter >> 0.9-m IKMT
	5	Neuston >> 0.15-meter >> 0.9-m IKMT
	6	Neuston ≈ 0.15-meter >> 0.9-m IKMT
	7	Neuston > 0.15-meter > 0.9-m IKMT
	8	no data
	9	insufficient data
	10	no data

Comparison C		Ranking
Group	1	Neuston ≈ 0.15-meter >> 1.8-m IKMT > Bongo
	2	Neuston > 0.15-meter >> 1.8-m IKMT >> Bongo
	3	Neuston > 0.15-meter > 1.8-m IKMT >> Bongo
	4	0.15-meter ≈ Neuston > 1.8-m IKMT >> Bongo
	5	0.15-meter > Neuston ≈ 1.8-m IKMT > Bongo
	6	insufficient data
	7	insufficient data
	8	no data
	9	insufficient data
	10	no data

≈ subequal (less than 2x different)
> greater than (by 2x - 9.9x)
>> much greater than (by 10x or more)

Table 8. Summary of comparisons of gears.

Comparison A	Number of times ranked		
	First	Second	Third
Neuston	4	1	1
1-Meter	2	4	0
0-Meter	0	1	5

Comparison B	Number of times ranked		
	First	Second	Third
Neuston	6	0	0
0.15-Meter	0	6	0
0.9-m IKMT	0	0	6

Comparison C	Number of times ranked			
	First	Second	Third	Fourth
Neuston	3	2	0	0
0.15-Meter	2	3	0	0
1.8-m IKMT	0	0	5	0
Bongo	0	0	0	5

Table 9. Average lengths and dry weights of selected larval brachyuran species.

Species	Stage	Average weight (mg)	Average carapace length (mm)	Number of crabs
Hyas araneus	ZI	0.038	1.07	29
	ZII	0.126	1.45	15
	Megalopa	0.489	3.20	6
Hyas coarctatus	ZI	0.046	1.11	45
	ZII	0.099	1.40	25
	Megalopa	0.183	2.20	9
Chionoecetes opilio	ZI	0.097	1.32	16
	ZII	0.41	2.12	31
	Megalopa	1.24	3.58	10
	mini ZII[a]	0.21	1.81	36
Geryon quinquedens	ZI	0.065	1.19	13
	ZII	0.117	1.55	30
	ZIII	—	—	—
	ZIV	0.137	—	2
	Megalopa	—	3.97	1
Carcinus maenas	ZI	0.008	0.52	12
	ZII	0.018	0.69	29
	ZIII	0.029	0.91	30
	ZIV	0.038	1.09	28
	Megalopa	0.066	1.23	24
Cancer borealis	ZI	0.009	0.68	30
	ZII	0.008	0.84	1
	ZIII	—	—	—
	ZIV	0.058	1.36	4
	ZV	0.109	1.63	5
	Megalopa	0.340	2.46	5
Cancer irroratus	ZI	0.011	0.62	33
	ZII	0.032	0.90	6
	ZIII	0.048	1.08	6
	ZIV	0.066	1.22	21
	ZV	0.237	1.77	24
	Megalopa	0.460	2.41	24

[a]A second much smaller "morph" is also found.

Table 10. Comparisons of average catch of larval crabs (per 1000 m^3 between day (0700-2000 h), night (2200-0500 h), and dawn + dusk (0500-0700 h and 2000-2200 h) for all gears fished concurrently.

LLS and SSIP cruises combined	Number of samples			Average catch		
	Day	Dawn + Dusk	Night	Day	Dawn + Dusk	Night
Cancer borealis all stages	2209	302	402	5.6	2.6	17.7
Cancer irroratus all stages	2209	302	402	59.8	90.7	371.1
Chionoecetes opilio all stages	2209	302	402	0.23	1.5	6.6

SSIP cruises 1977, 1978 only	Number of samples			Average catch		
	Day	Dawn + Dusk	Night	Day	Dawn + Dusk	Night
Cancer borealis all stages	515	147	293	0.5	3.4	23.1
Cancer irroratus all stages	515	147	293	5.8	174.1	496.5
Chionoecetes opilio	515	147	293	0.06	1.2	8.2

Table 11. A summary of comparisons of sizes of larval Brachyura from field collections and laboratory rearing.

Hyas araneus and Hyas coarctatus are both larger in field collections in all developmental stages than reported by Christiansen (1973) for larvae reared at 10.0 to 20.0°C.

Chionoecetes opilio was larger in field collections in all developmental stages than reported by Motoh (1973) for larvae reared at 7.0 to 13.0°C.

Cancer borealis was considerably larger in field collections in all developmental stages (up to 50% in the megalopa) than larvae reared in the laboratory by Sastry (1977a) at 15.0°C.

Cancer irroratus was considerably larger in field collections in all developmental stages (up to 20%) than larvae reared in the laboratory by Sastry (1977b) at 15.0°C.

Geryon quinquedens from field collections was very similar in size to specimens reared by Perkins (1973) at 15.0°C.

Carcinus maenas from field collections was very similar in size to, or slightly smaller than, specimens reared by Rice and Ingle (1975) at 15.0°C.

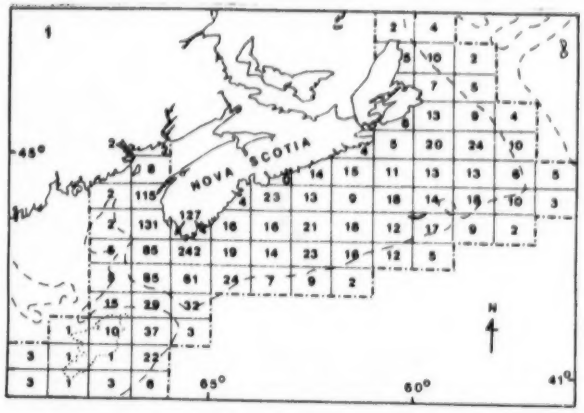

Fig. 1. Sampling grid of 1° Longitude by 0°30' Latitude along the Nova Scotia shelf and the number of neuston samples taken in each grid.

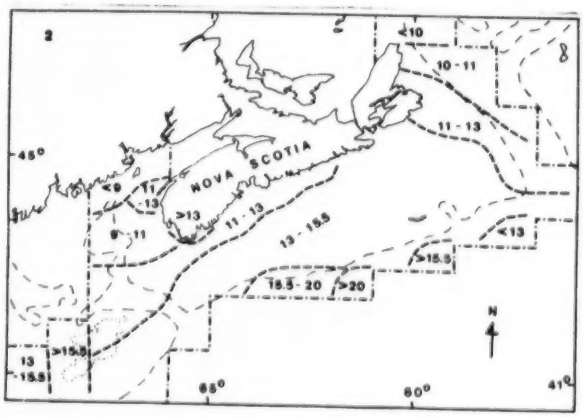

Fig. 2. Mean summer distribution of temperature (°C) along the Nova Scotia shelf, 1977-78.

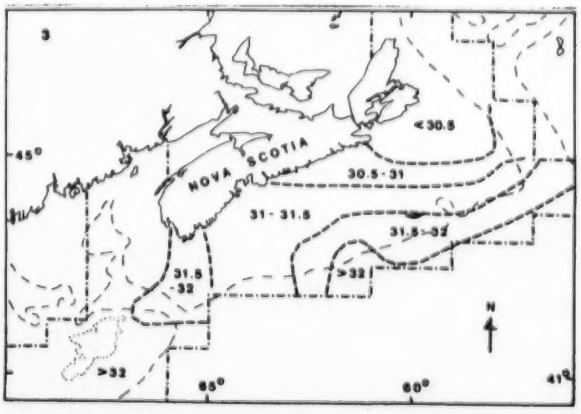

Fig. 3. Mean summer distribution of salinity (o/oo) along the Nova Scotia shelf, 1977-78.

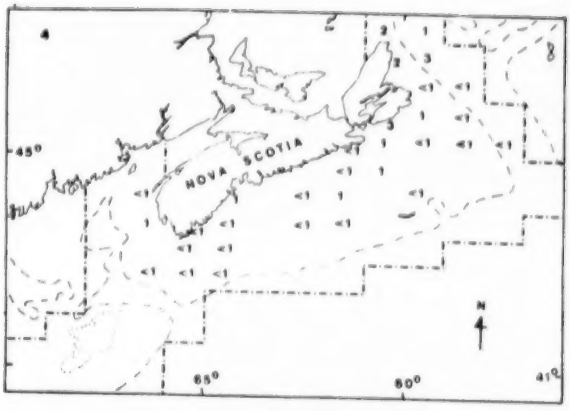

Fig. 4. Distribution of Chionoecetes opilio zoeas, average number per neuston tow (≅550 m³). Abundances are ranked as: <1 = less than 1, 1 = 1-9, 2 = 10-99, 3 = 100-999, 4 = 1000+.

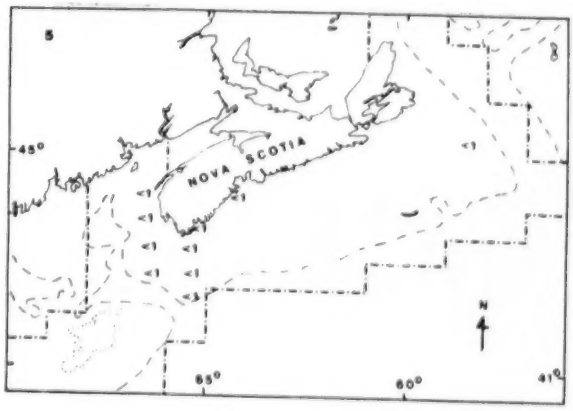

Fig. 5. Distribution of C. opilio megalopas; abundance ranks as in Fig. 4.

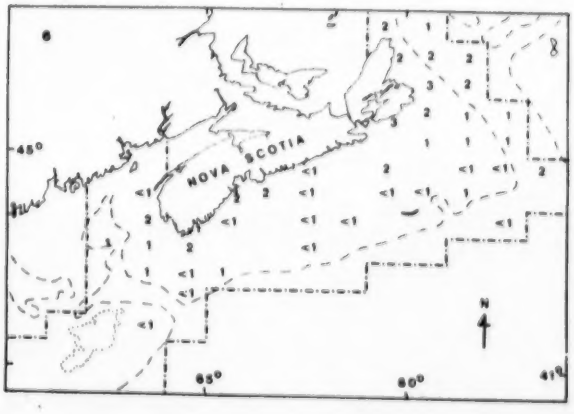

Fig. 6. Distribution of Hyas araneus zoeas; abundance ranks as in Fig. 4.

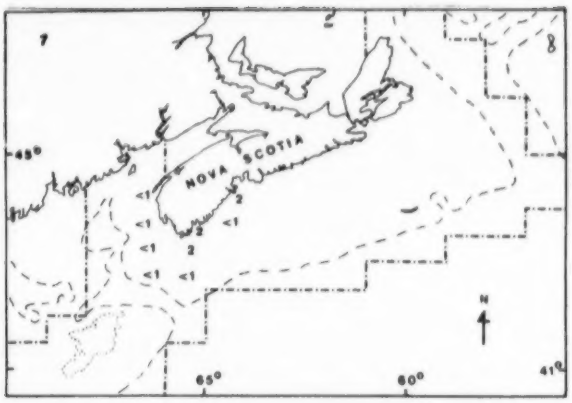

Fig. 7. Distribution of H. araneus megalopas; abundance ranks as in Fig. 4.

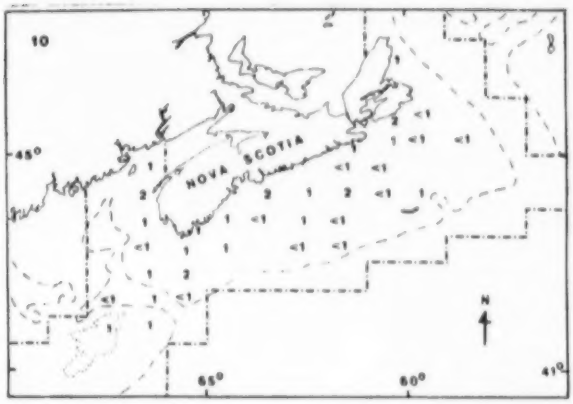

Fig. 10. Distribution of Cancer borealis zoeas; abundance ranks as in Fig. 4.

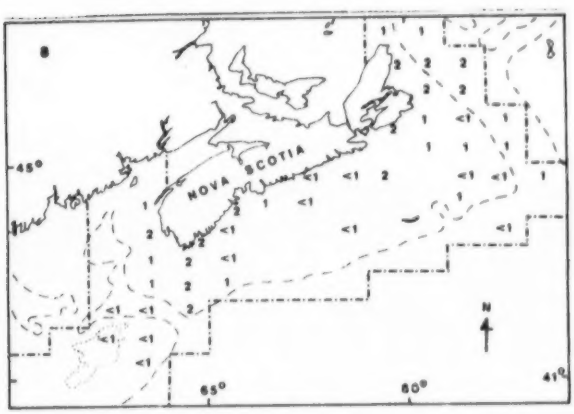

Fig. 8. Distribution of H. coarctatus zoeas; abundance ranks as in Fig. 4.

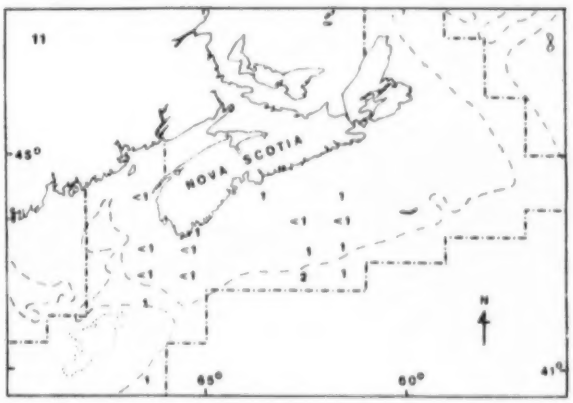

Fig. 11. Distribution of C. borealis megalopas; abundance ranks as in Fig. 4.

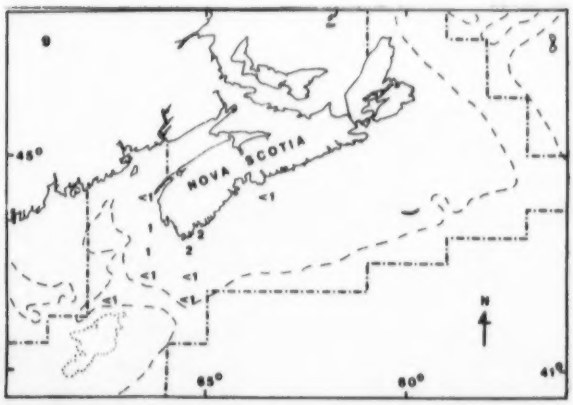

Fig. 9. Distribution of H. coarctatus megalopas; abundance ranks as in Fig. 4.

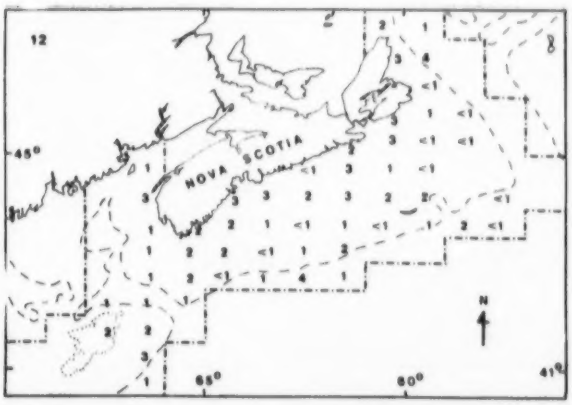

Fig. 12. Distribution of C. irroratus zoeas; abundance ranks as in Fig. 4.

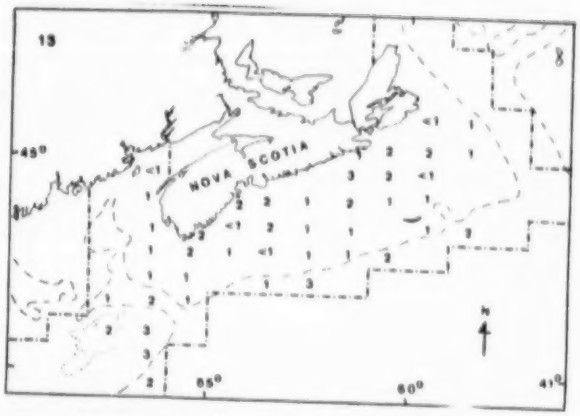

Fig. 13. Distribution of C. irroratus megalopas; abundance ranks as in Fig. 4.

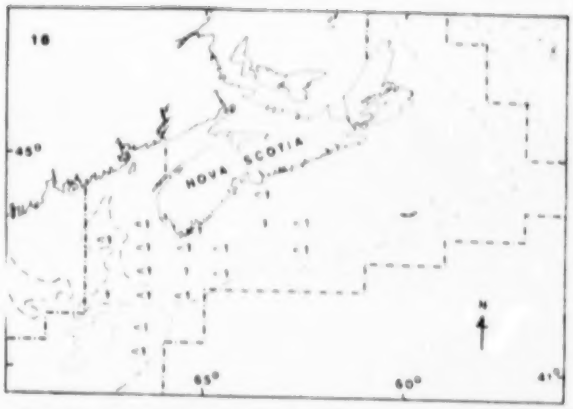

Fig. 16. Distribution of Geryon quinquedens zoeas; abundance ranks as in Fig. 4.

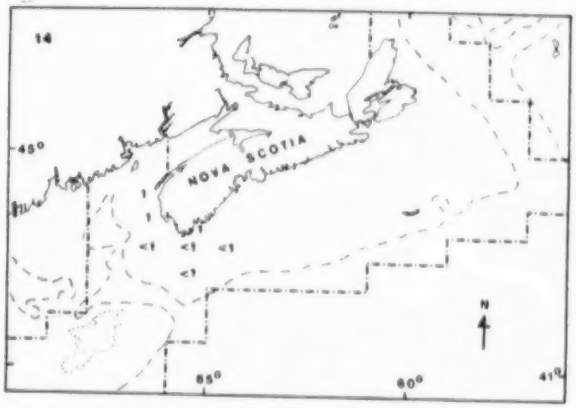

Fig. 14. Distribution of Carcinus maenas zoeas; abundance ranks as in Fig. 4.

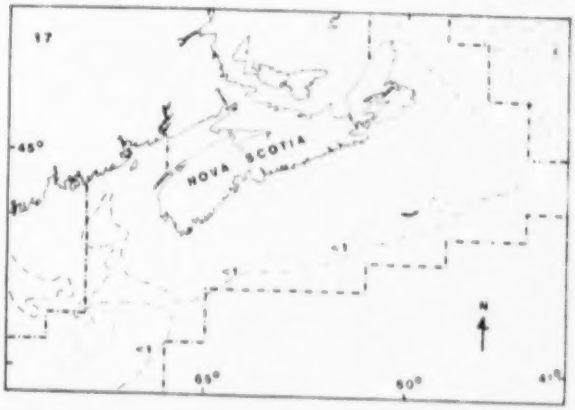

Fig. 17. Distribution of Acanthocarpus alexandri megalopas; abundance ranks as in Fig. 4.

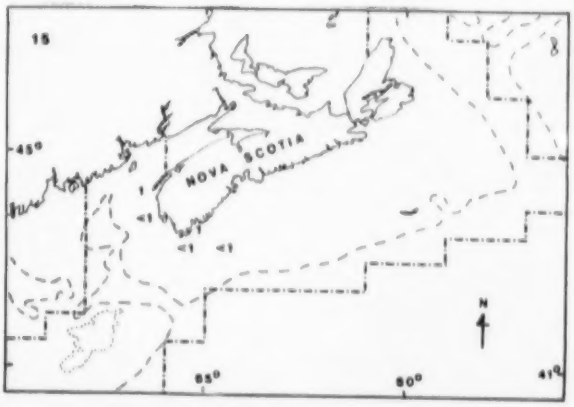

Fig. 15. Distribution of C. maenas megalopas; abundance ranks as in Fig. 4.

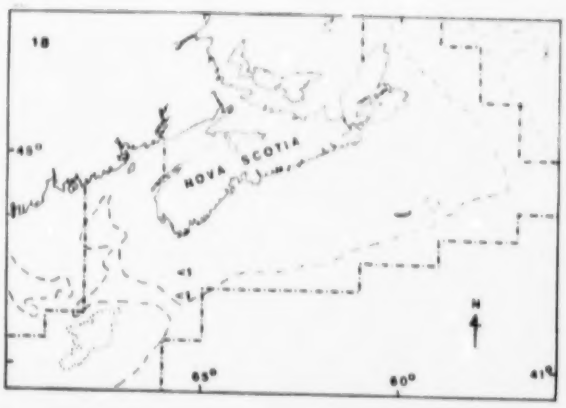

Fig. 18. Distribution of Neopanope texana sayi megalopas; abundance ranks as in Fig. 4.

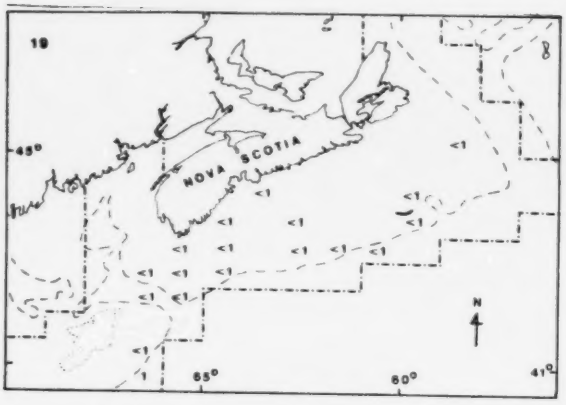

Fig. 19. Distribution of Ovalipes ocellatus megalopas; abundance ranks as in Fig. 4.

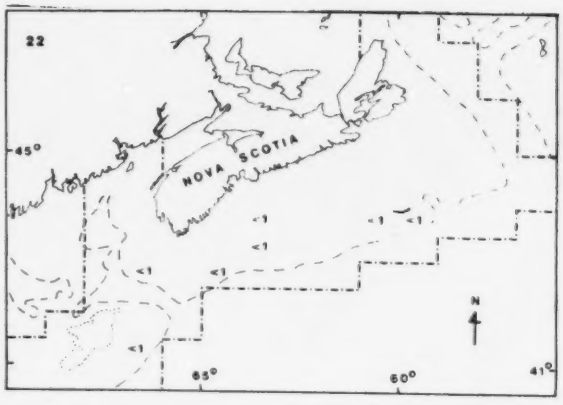

Fig. 22. Distribution of Calappa flammea megalopas; abundance ranks as in Fig. 4.

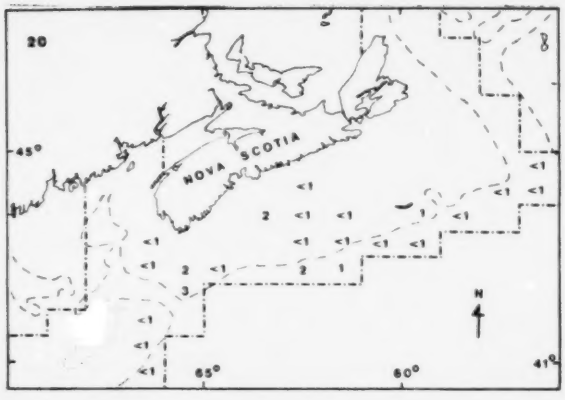

Fig. 20. Distribution of Cycloës bairdii meglaopas; abundance ranks as in Fig. 4.

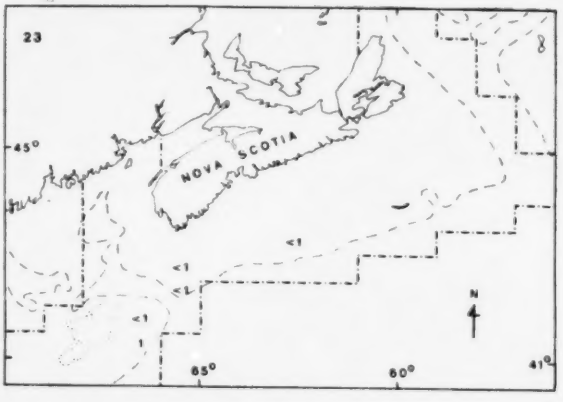

Fig. 23. Distribution of Lyreidus bairdii megalopas; abundance ranks as in Fig. 4.

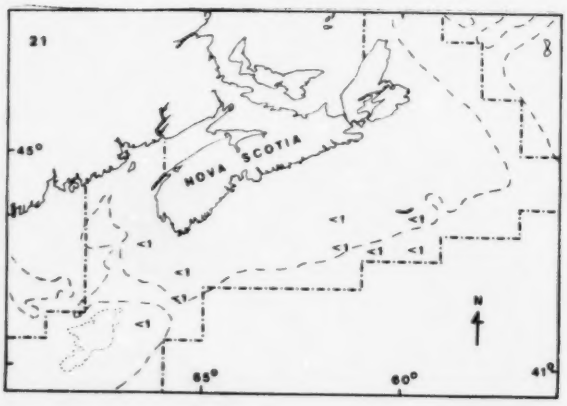

Fig. 21. Distribution of Parthenope pourtalesii megalopas; abundance ranks as in Fig. 4.

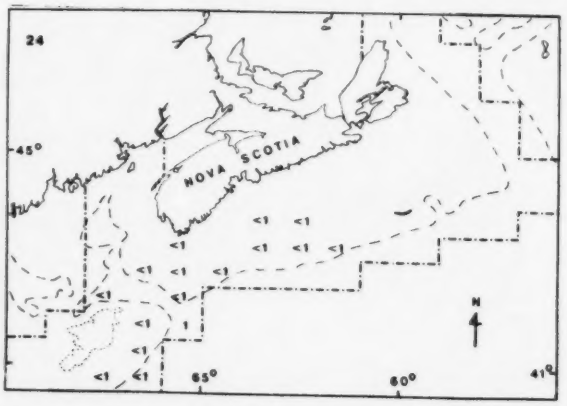

Fig. 24. Distribution of Dromidia antillensis megalopas; abundance ranks as in Fig. 4.

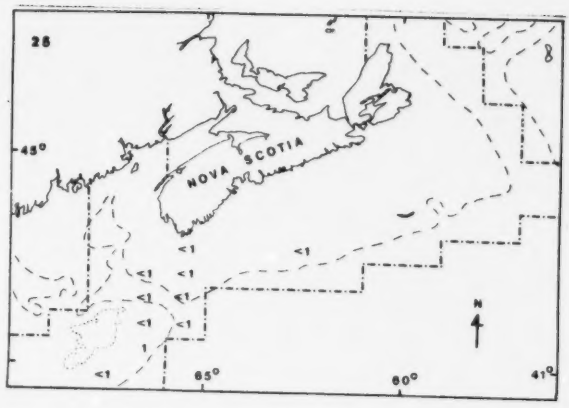

Fig. 25. Distribution of Portunid #3 megalopas; abundance ranks as in Fig. 4.

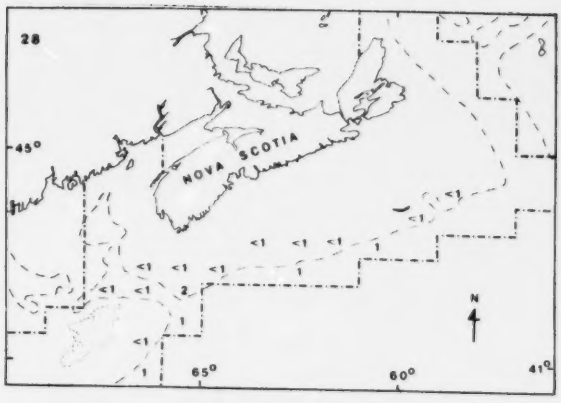

Fig. 28. Distribution of Portunid #2 megalopas; abundance ranks as in Fig. 4.

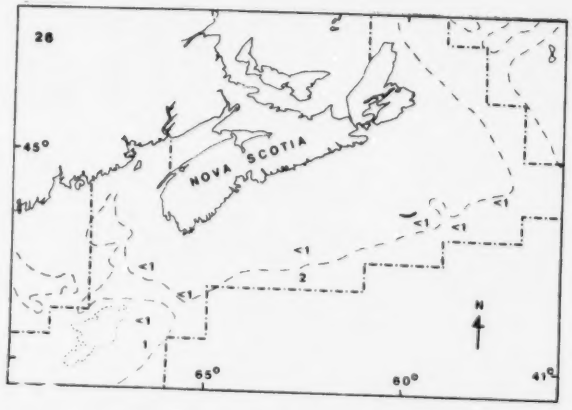

Fig. 26. Distribution of Portunid #4 megalopas; abundance ranks as in Fig. 4.

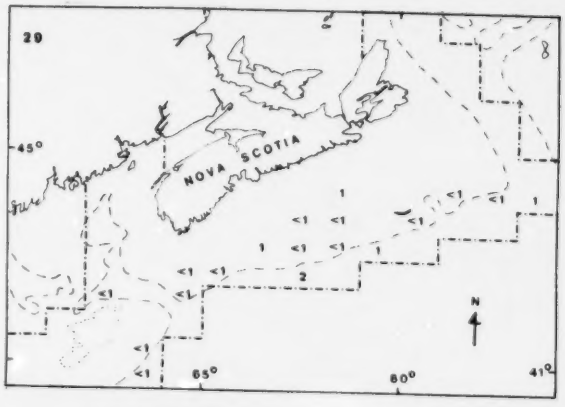

Fig. 29. Distribution of Portunid #1A megalopas; abundance ranks as in Fig. 4.

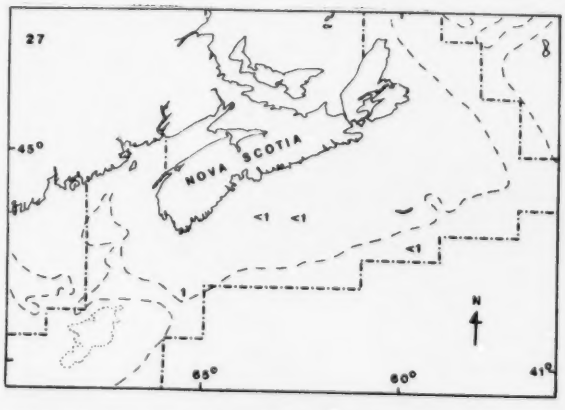

Fig. 27. Distribution of Portunid #5 megalopas; abundance ranks as in Fig. 4.

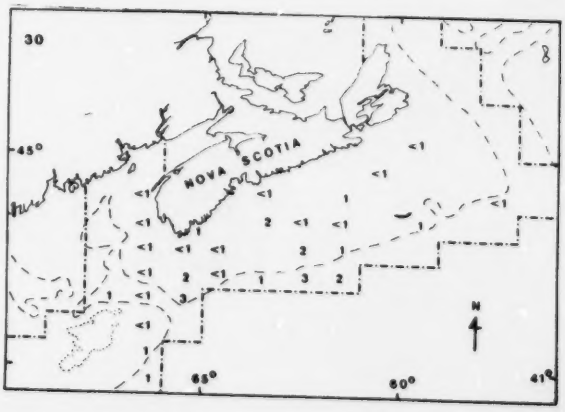

Fig. 30. Distribution of Portunid #1B megalopas; abundance ranks as in Fig. 4.

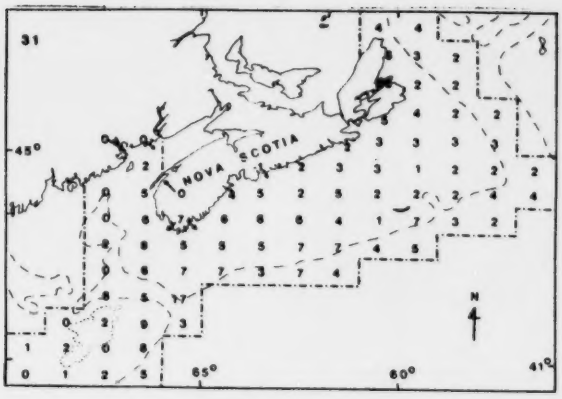

Fig. 31. The maximum number of species observed in a single haul (any gear) in each grid.

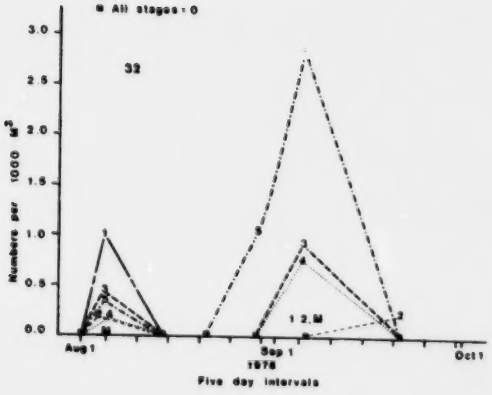

Fig. 32. Seasonal occurrence (average number per 1000 m^3) of the developmental stages of Cancer borealis during August - September 1978 in the LLS cruises 30-39 (stations 100-200). Numbers 1-5 represent respective zoeal stages; M = megalopa stage.

POOR

QUALITY

ORIGINAL